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REMARKS ON NERVE-GRAFTING.

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THIS operation was, I believe, new to surgery when my colleague, in January of last year, communicated to the Clinical Society of London an account of the first case in which he had performed it, and exhibited his patient. Experiments in grafting nerves in the lower animals may have been previously made in other countries, but of this I am not sure. To Mr. Mayo Robson, I believe, is due the credit of having devised and performed it in the human subject. Since then several other cases have been undertaken in the Leeds General Infirmary, presenting considerable variety.

It seems to me, therefore, desirable to review these cases, the different circumstances under which the operation has been performed, the modifications of procedure, and the results obtained.

Nerve-grafting consists in the insertion of a fresh piece of nerve, newly taken from man or animal, into the gap left by the removal or destruction of a portion of a nerve in its continuity, whether by design or accident, and in suturing it into position. This has been done five times in all here—twice by Mr. Robson, once by Mr. Ward, and twice by myself. Of these, one (Mr. Robson's first case) was performed forty-eight hours after division of the median while removing a neuroma. Two were deliberately planned; the one for tumour involving a nerve, the other for paralysis due to an old cicatrix. The remaining two were done under emergencies; the first for the accidental removal of a portion of the sciatic nerve while excising the hip in a child—where the same piece was replaced in its former position; and the second was for a lacerated wound of forearm, involving the destruction of two inches of the ulnar nerve. In all five cases, sensation, entirely lost before, began to be restored after an interval varying from thirty-six hours to eighteen days, and steadily improved.

I will now relate the cases as briefly as I can, and afterwards offer a few remarks upon them. The first, having been already published,[1] I will only sketch, if I may, very cursorily.

CASE I.—M. B., a girl, aged 14, came under the care of Mr. Robson in September, 1888, for a tumour the size of a hen's egg on the right forearm, which had been growing six years. It was situated just above the wrist, and, being a source of great inconvenience as well as deformity, she sought for its removal. Upon incising the integuments, the tumour bulged through the wound, and was easily separated from its cellular bed, leaving the mass attached above and below to a cord which appeared to be inseparably blended with it; the attachments had therefore to be cut through. The microscope showed the cord to be composed of nerve tissue, and, on the patient recovering from the anæsthetic, the parts of the hand supplied by the median were found to be devoid of sensation.

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[1] BRITISH MEDICAL JOURNAL, February 2nd, 1889.

Mr. Robson arranged to graft the sciatic nerve of a rabbit into the gap of the median. But learning that our colleague, Mr. Ward, was about to amputate a thigh on the second day after, they agreed to arrange their operations at the same time; so Mr. Robson was enabled to utilise the posterior tibial nerve of the amputated limb, which was taken straight from one theatre to the other in warm carbolic solution, and transferred at once into the prepared forearm. Two inches and a half of the nerve were utilised, the ends being attached to the proximal and distal portions of the median with a fine catgut suture, without the slightest tension, either on the stitches or on the nerve; the wound was well washed out with perchloride of mercury lotion, and carefully sutured. Healing occurred by first intention. The grafting was performed forty-eight hours after the tumour had been removed.

Thirty-six hours after the nerve had been grafted sensation had so far returned in the parts supplied by the median that the touch of a pencil could be localised. Day by day sensation became more and more distinct, until when shown to the members of the Leeds and West Riding Medico-Chirurgical Society, five weeks after the operation, it was so perfect that the slightest touch could be localised, and although there was manifest diminution in volume of the adductor and flexor brevis pollicis, they had recovered some power of action.

The girl lives at a distance (near Lancaster), and has not been seen recently by Mr. Robson, but I understand he has learned from her local surgeon that the result is almost perfect.

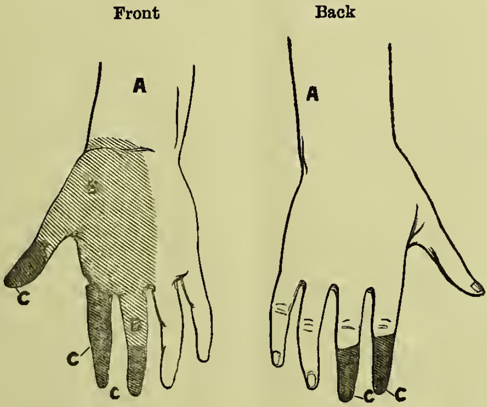
Case ii.—R. W., labourer, Morley, aged 42, came up to Mr. Ward's out-patients in July, 1888, complaining of an extremely painful lump 2½ inches above the inner condyle of the right humerus. Eight months before he had a blow there, and four months after that he noticed a lump in that situation, which had gradually increased up to that time, and was then the size of a large marble. The tumour was freely movable in a lateral direction, but very painful on pressure, which also caused pain and tingling in the thumb, index and middle fingers. This Mr. Ward removed, under cocaine, the skin incision causing no pain. He found the growth was surrounded on all sides by fibres of the median nerve, but shelled out quite easily, causing most agonising pain. The wound healed by first intention. Microscope showed the growth to be a pure myxoma.

In November of the same year he was admitted as an in-patient with recurrence of his former symptoms, and with a hard fusiform swelling in the site of the previous tumour, not so well defined or so freely moveable.

The following notes were made on his admission:—Range of movements of right hand and forearm unimpaired, but weak. On expanding the fingers a coarse tremor affects the whole forearm. Grasp of right hand, 13 lbs.; that of the left, 63 lbs., measured by dynamometer. On exertion patient complains of a sharp darting pain running from the ends of index and middle fingers up the middle of forearm to the situation of the tumour. No loss of sensation anywhere. There is hyperæsthesia of the adjacent sides of index and middle fingers from the proximal interphalangeal joints to the tips. On the inner side of the upper arm, 2½ inches above the elbow, beneath the cicatrix of the former incision, but apparently not attached to it, is a fusiform hard body about 1 inch long by ⅓ inch broad, which is very painful on handling. The forearm is wasted.

With the intention of grafting a sound piece of nerve into the place of the affected median, Mr. Ward made him out-patient until an opportunity should arise for obtaining the required nerve.

On January 1st, 1889, he was readmitted, and on the 10th an amputation of arm being performed, Mr. Ward timed his operation to suit, and had the median nerve carefully removed from the amputated limb, whilst he proceeded to expose, under ether, the fusiform lump on his patient's arm ; it had a firm fibrous appearance, and was found to be attached to the median nerve, which lay beneath it. It did not shell out as before, but required dissecting away from surrounding parts, the nerve itself being also removed to the extent of 1¾ inch, the points of section being apparently through healthy nerve tissue. He then placed his graft in position, consisting of 2¼ inches of healthy median nerve, sutured it with fine catgut, closed the wound, and dressed it antiseptically. The microscopic examination of the tumour showed it to be myxomatous.



Case II.—Condition on January 10th, 1889. A. Unshaded—Sensation normal. B. Light Shading—Sensibility diminished. C. Dark Shading—Anæsthetic.

January 12th. There is numbness and tingling over the whole arm and hand.

January 20th. The wound perfectly healed.

February 2nd. Slight thickening along the course of cicatrix, no pain, says that the fingers feel cold, but they are quite warm to the touch. Grasp is improving. Thumb and index very weak. The hand looks wasted, especially the thenar muscles.

February 6th. Made an out-patient. Progress made was very slow, both in return of sensation and power.

July 26th, 1890. Seventeen months having elapsed since the nerve-grafting, the following notes were taken:—There was a slight degree of wasting of fore-arm; marked wasting of the abductor and opponens pollicis, the thenar eminence being entirely absent, and a marked depression over the position of these muscles. Sensation was normal as far down as the wrist: below this, sensation over the median area was described as "dull." The touch of a pin could everywhere be distinctly localised. There were no signs of "glossy" fingers: but the remains of an old bulla, trophic in origin, were seen over the tip of the index. The grip of index and middle finger was good. Movements of index and middle fingers were normal in range, though weaker than normal. The movements of the thumb were limited to flexion, extension, and adduction: abduction and opposition being entirely wanting. He could lift fairly heavy weights, and was gaining his livelihood as a light porter.

Case iii.—W. R., aged 29, a silk-dresser, was admitted in January, 1890, into Leeds General Infirmary under Mr. Robson, with the following history:—Seven months ago he fell on a scythe, receiving a deep cut on the lower and inner part of the arm. The surgeon who dressed it said the main artery was divided, and that the two ends of a nerve were sewn."

Condition When Admitted.—There is a scar on the inner aspect of the right arm extending from a point two inches above and to the inner side of the olecranon, obliquely upwards and forwards for about 3 inches, to the inner side of the prominence of the biceps. On careful examination it was made out that motion and sensation are entirely absent throughout the area of distribution of the ulnar and median nerves, while the parts supplied by the musculo-spiral are active. Tested by the electrician, it is found that the extensors react to faradism while the flexors do not.

January 30th.—Mr. Robson started his incision between the internal condyle and the olecranon an inch below the lower extremity of the scar, continuing it up to and along the length of the cicatrix, and subsequently made a second transverse incision at right angles to the first, about an inch above the bend of the elbow.

The ulnar nerve, when exposed above the internal condyle, was found to be a good deal implicated in the scar, and was cleared by dissection until healthy nerve was found above the middle of the arm. The nerve appeared continuous to the eye, but to the touch a place could be felt where there was evidently a gap in the nerve tissues bridged across by fibrous tissue, the upper end of the nerve being bulbed. This was at the point where the scar crossed the course of the nerve. A long search for the median among the changed structures resulted at last in discovering the upper end, bulbed, well beneath the belly of the biceps, and the lower end, which also had an expanded extremity, just above the elbow-joint. Another small nerve, probably the internal cutaneous, was found divided, its upper end having become united to the upper end of the ulnar nerve.

The fibrous tissue uniting the two portions of the ulnar was now excised, and healthy nerve tissue brought together and sutured with fine catgut. The two ends of the internal cutaneous were next sutured, and finally a piece of spinal cord, a good 2 inches in length, from a freshly killed rabbit, was inserted between and sutured to the refreshed ends of the median, the inserted cord lying loosely without tension. Lastly, the edges of the wound were brought together and sutured, a firm antiseptic dressing applied, and the limb put up in a semi-flexed position upon an external angular splint.

February 10th. Patient can feel the scratch of a pin on the flexor aspect of the first phalanx of the thumb, and also at the root of the index finger. He can tell when the hairs on the back of the first phalanges of the ring and little fingers are pulled, but cannot feel the scratch of a pin in that position.

February 17th. Can feel along whole palmar surface of thumb and of proximal phalanx of index finger.

March 4th. Sensation seems creeping slowly along the first finger, and to be present over the whole of the palmar area supplied by the median, and extending as far down as the web of the fingers and a short distance along the middle finger. As yet there is no marked improvement along the ulnar distribution.

March 30th. Patient begins to have sharp shooting pains along distribution of ulnar.

April 1st. Flexors of forearm begin to react visibly to kathodal closing current, but the muscles of the thenar eminence do not. No reaction to faradism yet.

April 30th. Sensation returning at the back of ring finger. Slight flexion of wrist and fingers possible by volition. Flexors will now react to a constant current of 5 milliampères.

June 13th. Nutrition of hand much improved; also much more warmth in it. Patient says he can pick up small objects. Grip is not very powerful, but much improved. Flexion of wrist and power of adduction of thumb considerably increased. As yet there is no sensation over ulnar distribution. Can flex the fingers on the palm fairly well.

Case iv.—W. M., aged 5, a tolerably plump but pasty-looking little boy, was admitted under my care on January 1st, 1890, suffering from symptoms of advanced hip disease on the left side. There was a large abscess on the left buttock, which, on being opened antiseptically on January 9th, was found to communicate with the hip joint, and on introducing a finger through a posterior opening in the capsule I felt the head of the femur quite carious.

On February 6th I operated for excision of the hip. I adopted a lateral and somewhat posterior incision in the axis of the limb, partly to utilise the opening where the abscess had been incised, and partly with a view to secondary amputation of the thigh as an ultimate proceding, should the pelvis, as I feared, prove to be much diseased. I found the tissues matted, and the muscles around infiltrated with gelatinous material, so that after the removal of the head and neck of the femur, and after picking out as much of the carious acetabulum as I could, I endeavoured to remove with scissors some of the diseased tissues around the sac of the old gluteal abscess. In so doing I discovered, to my horror, that I had removed a piece of the sciatic nerve nearly an inch in length. Immediately, however, the piece of nerve was cleaned from the diseased material which surrounded it, and with a single fine catgut suture at each extremity, I replaced it in position, closed and drained the wound, and fixed the limb and pelvis as firmly as possible in a Bryant's splint. This enabled us to irrigate the wound daily with antiseptic lotions, and to keep it sweet and free from the lodgment of discharges.

The anæsthesia of the limb on the day following the operation was complete, and I watched it with great anxiety. But on the fifth day after, to my astonishment and relief, sensation began to return in the toes. Day by day there was improvement, and by the sixteenth day the child, who was very intelligent, could localise the touch of a pin point in any part of the limb.

The excision wound subsequently healed, and the child went out on a light Thomas's splint. The carious disease of the pelvis has since somewhat extended, but the parents will not permit anything further; and when I looked the child up the other day he was sitting in a rocking-chair, and wagging his leg over the side of it with apparent satisfaction. The touch of a pencil could be localised all over, but there seemed to be a certain dulness of feeling in the foot.

Case v.—C. P., aged 22, miner, was admitted on April 19th, 1890, under my care, with a severe lacerated wound of the right forearm and paralysis of the inner half of the hand, corresponding with the distribution of the ulnar nerve.

Patient is a miner, and was working in the mine two hours previous to my seeing him, superintending a coal-getting machine, when the shaft caught his arm against a fixed part of the machine and inflicted the wound above mentioned. On examination he was bleeding profusely from the ulnar artery, which was torn across. The flexor sublimis, flexor carpi ulnaris, and palmaris longus were torn through, and the ulnar nerve was missing from its normal position. On searching, the two ends were found two inches apart, the distal end having disappeared behind the upper margin of the annular ligament. After securing the bleeding vessels, the wound was cleansed and asepticised as far as possible by long irrigation and drenching in bichloride of mercury solution 1 in 3,000. The extent of the wound longitudinally was over six inches. No human nerve being available, a live rabbit was now procured and killed, and the two sciatic nerves very carefully removed and immersed in weak warm carbolic lotion. Two and a half inches of each nerve—which were together scarcely equal in calibre to the divided ulnar—having been laid in the gap, were sutured into position with a single stitch of fine catgut through each nerve to the refreshed ends of the ulnar. The torn muscles were then stitched, and the skin, which did not appear much bruised, was brought together and sutured. The whole limb, dressed antiseptically, was put on a posterior wire splint.

The dressings were not touched for five days, but on being taken down on April 24th there was great strain on the skin flaps, and on removing the stitches a large quantity of brownish blood-stained pus escaped, and the wound looked in a nasty condition, part of the flexor carpi ulnaris having sloughed away. The wound was well irrigated, and poultices of salicylic wool applied. The nerve graft was not seen.

Although the untoward state of things was disheartening, it could cause no surprise, considering the amount of contusion and laceration the muscles had undergone. In a few days the parts assumed a more healthy appearance, however, and in a week's time a crop of florid granulations lined the wound.

On the eighteenth day, to my surprise, there was a distinct beginning of sensation in the ring and little fingers. On the twenty-fifth day (May 12th) the wound was closing in; the sensation in the two fingers and hypothenar eminence was increasing steadily, and some power of movement had commenced.

On May 22nd. The wound was almost entirely healed. Faradism had been employed several times with full reaction on the muscles supplied by the median and radial, but not in those supplied by the ulnar. This was now changed for the constant current daily.

The man becoming impatient, was allowed to leave the hospita five weeks after admission, and from that time was only seen twice as an out-patient. Upon sending for him last week (July 24th), just three months after his accident, the condition was as follows: Sensation complete in all the fingers on both aspects, with the exception of the last two phalanges of the little finger. Can flex all his fingers on the palm, except that the little finger stops short of the palm by half an inch. This, considering the existence of a cicatrix $5\frac{1}{2}$ inches long just above the wrist, is very surprising. Has a fairly strong grip. Has returned to his work in the pit, and can work his machine, which requires him to grasp a handle.

It will be observed that the five cases which I have related all vary from one another very considerably, and that in many different ways:—

1. In the cause which gave occasion for performing the operation.

2. In the condition of the parts at the time.
3. In the material of the graft.
4. In the interval of time that elapsed between the severing of the nerve and the insertion of the new piece.
5. In the subsequent behaviour of the wound.
6. In the period at which the return of sensation began to be manifested. And in various other circumstances.

The only points which are common to them all are that a gap in the continuity of a nerve was supplied by a piece of nerve tissue, and that in each case function, entirely lost before, was more or less restored.

My object in this paper is not to venture upon any histological theory as to the manner in which the small amount of clinical facts at my disposal may be explained, but to endeavour to draw some practical conclusions from our experience hitherto, such as may encourage to further trials in the same direction. I would, then, submit as follows:—

(*a*) That absolute loss of a piece of nerve and the substitution of a new piece constitute a totally different condition of things from the simple suturing of a divided nerve.

(*b*) That, whether there be such a thing as "primary union" of nerve fibres or not, in the case of recently divided nerves united by suture, this process cannot take place in nerve-grafting, and yet that union of some kind rapidly follows this operation, restoring function.

(*c*) That healing by first intention does not appear to be be indispensable to success, or even asepsis, because suppurative inflammation, and even the sloughing of muscle in the immediate neighbourhood of the new graft may occur without destroying its vitality.

(*d*) That restoration of muscular movements is always delayed, sometimes until long after complete sensation is re-established.

(*e*) That, while mindful of the free interlacement of nerves in both upper and lower limb, the results obtained by nerve-grafting in a variety of cases are not to be altogether explained in this way.

1. The first proposition is, of course, self-evident; and I make it only to clear the ground, because in the discussion which followed the reading of Mr. Robson's paper there appeared to have been some confusion between nerve-grafting and nerve-suturing.

2. It has been laid down authoritatively "thst the divided ends of a nerve which has been cut across readily reunite by cicatricial tissue, but that the cut ends of the fibres themselves do not thus unite." This seems highly probable, if for no other reason than that, whether the ends be held in contact by suture or simply left to Nature, there can scarcely be perfect apposition of the individual fibres. I cannot, therefore, see that the theory of "primary union" is tenable; but, provided the cut ends of the nerve be kept in tolerably accurate contact, the interposed layer of cicatricial tissue will be a very thin one. The doctrine of the invariable degeneration of the peripheral portion of the divided nerve does not appear to be so universally held. That this process is not invariable seems to be shown by the fact that function is sometimes restored where the vicarious action of nerve interlacement has not come to the rescue, as was the case in the man (Case No. III) whose hand was paralysed for six months from a wound that had divided both median and ulnar nerves, but in whom the subsequent grafting of the one nerve and reuniting the refreshed ends of the other was followed by gradual restoration of sensation in the median tract, and tolerably good use in the hand, though sensation in the ulnar tract did not return so promptly.

3. Among the conditions recommended by Mr. Robson for performing the operation of nerve-grafting was strict asepsis. Naturally we should always aim at this, and in a deliberately planned operation we might generally expect to carry it out, and obtain healing of the wound by first intention; but that success does not absolutely depend on these favourable conditions is proved by Case No. v, where the operation was one of emergency, and where, despite every care in the cleansing of the wound, the amount of injury to the muscles was followed by suppuration, and even some sloughing of muscular tissue. This at the time destroyed my hopes of any good resulting; and yet, strange as it must appear, after three months' interval, the patient comes from his work to show a useful well-nourished hand, with not only sensation restored over the whole area of ulnar distribution, except the two last joints of the little finger, but also a good grip, flexion of all the fingers on the palm, and the ability to work his coal-getting machine in the pit almost as well as before his accident.

4. That the restoration of muscular movements is longer delayed than the recovery of sensation—sometimes for months, and sometimes very imperfectly, if at all—is perhaps not to be wondered at, since the first effect of cutting off the nerve supply of a part is the wasting of the muscles from trophic lesion, and this would be naturally increased by want of use; but after sensation had begun to be re-established the regular use of the constant electric current largely promoted the nutrition of the muscles. Why the motor elements of an injured nerve are slower than the sensory elements in recovering their function does not appear to be understood.

5. It has been argued that the well-known fact that branches of different nerve trunks in the extremities not infrequently join with one another is a sufficient explanation of those cases where, for example, the median has been sutured after accidental division, with the effect that sensation has returned in the parts supplied by the nerve in a few hours. "Such return of sensation, it is alleged, is probably due to the supplementary action of the interlacing nerve fibres bound up with other trunks......so that the sensory impressions are returned by another route." (Treves.)

But these communications of nerve fibres are a very different thing from vascular anastomoses, which enable a part cut off from its normal blood supply to avail itself of a collateral circulation; for it has been shown that "the medullated fibres themselves, in their course along the nervous cords, never anastomose." (Quain.)

In conclusion, I do not claim either for my colleagues or myself an unqualified success in any one case hitherto. I think, however, that we have made some valuable experiences. The cases exhibit a sufficiently varied series to suggest in how many different circumstances the operation of nerve-grafting may be useful; and they record a degree of success which I may venture to call encouraging.

Perhaps the best results are more likely to be achieved in primary operations upon injured nerves rather than where they have been for a length of time involved in a cicatrix, or where the nerve is itself a seat of disease; but the cases are as yet too few to generalise upon, and we must await the experience to be gained from fuller trial.